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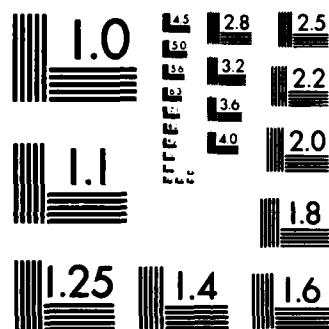
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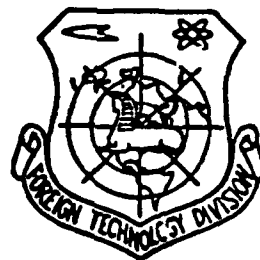
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A LONG LIFE CO₂ LASER

by

Cai Lijuan, Yu Linxiu and Zhang Kenian



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A LONG LIFE CO₂ LASER

by Cai Lijuan, Yu Linxiu and Zhang Kenian
(Institute of Laser Technology, Shanghai)

Abstract

It is shown experimentally that three major factors must be considered to obtain a CO₂ laser with long life. They are: 1) elimination of slow gas leakage; 2) selection and oxidation of electrode material; 3) decreasing the decomposition of CO₂ molecules. Our method was: the laser tube is not dried but filled with water vapor, the electrode material must be degassed in a vacuum and oxidized by filling oxygen gas. When pure silver electrodes are employed, the gas mixture constitutions are separately 1) CO₂-N₂-He-Xe-H₂O; 2) CO₂-CO-He-Xe-H₂O; 3) CO₂-N₂-CO-He-Xe-H₂O, the operating lives reach 1) 10,476 hours; 2) 9,185 hours (still in operation); 3) 9,207 hours (still in operation). When pure nickel electrodes are used, the gas composition is CO₂-N₂-He-Xe-H₂O and the operating life reaches 1,644 hours.

The operating life of a sealed CO₂ laser is a problem in

need of fast solution. In the last ten or more years a great deal of domestic and foreign testing has been done on sealed CO_2 lasers and there have been noticeable achievements. Foreign nations have reported that when a silver-copper (internal oxidation) alloy is used as the electrode material in a CO_2 -CO-He-Xe gas mixture, the CO_2 laser output power is 1 watt and its life reaches 12,000 hours.

We drew from foreign tests and at the same time based on the actual circumstances of existing laboratory conditions and operating CO_2 lasers, tests were carried out on lasers with 25-30 watt output power and an 800 millimeter discharge length whereupon an operating life of 10,000 hours was able to be obtained.

I. Test Conditions

The serial numbers were A, B, C, D, E, F and G. The effective discharge length was 800 millimeters, the inner diameter of the discharge tube was 8 millimeters, the cavity structure was a plane-spherical cavity, the total reflector curvature radius was 3 meters, the output window plate was a germanium wafer, and there was non-coated uniform output. Fig. 1 shows the structure of the CO_2 laser. The material used was GG17 hard glass.

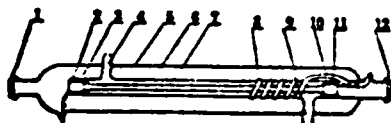


Fig. 1 Structure of the CO₂ Laser

- Key:
1. Output window (germanium wafer)
 2. Cathode
 3. Cathode cover
 4. Outfall
 5. Receiver
 6. Water-cooled tube
 7. Discharge tube (8 millimeter inner diameter)
 8. Gas return tube
 9. Water intake
 10. Anode cover
 11. Anode
 12. Reflector plate (R is 3 meters, gold plated)

There are two types of electrode material, nickel and silver hollow cylinders, and both must be degassed in a vacuum and oxidized by filling oxygen gas. All of the manufacturing techniques for the lasers are the same. The laser tube is not dried but filled twice with He gas for discharge degassing and adding H₂O. Vacuity is 5×10^{-5} torr. The gas compositions of these seven lasers are listed separately in table 1.

编 号	电极 材料	气 体 比 例 10					总气 压 (托)
		CO ₂ : N ₂ : O ₂ : He			X ₀ (托)	H ₂ O (托)	
A	镍5	1	2	7	0.5	0.2	25
B	镍4	1		1.5 7	0.5		24
C	镍5	1	2	7	0.5	0.2	25
D	镍6	1		1.5 7	0.5	0.2	27
E	镍7	1	1	1 7	0.5	0.2	28
F	镍8	1		1.5 7	0.5		24
G	镍9	1		1.5 7	0.5		24

Table 1

- Key: 1. Serial number
 2. Electrode material
 3. Nickel
 4. Silver
 5. Silver
 6. Silver
 7. Silver
 8. Silver
 9. Nickel
 10. Gas ratio
 11. (Torr)
 12. (Torr)
 13. Total gas pressure (torr)

The discharge is: when the direct current discharge (whole wave integral flow) operates in a discharge current with N₂ in the mixed gas it is 18 to 20 milliamperes and when it is in a CO (when there is no N₂) discharge current it is about 16 milliamperes. The operating mode is: it operates continually 24 hours each day, the water cooling temperature is a constant temperature (room temperature), the reflector plate and output window both use water cooling, and when the laser is operating it has a water and electric breaking controller. So-called laser

life is the output power of the component which changes with the operating time. When the laser's output power declines to 70% of the initial power, the operating life is terminated.

II. Test Results

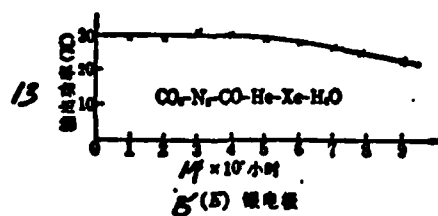
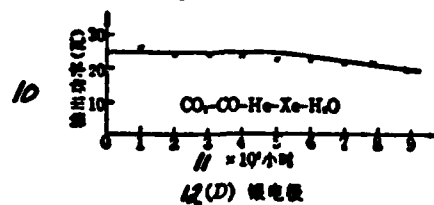
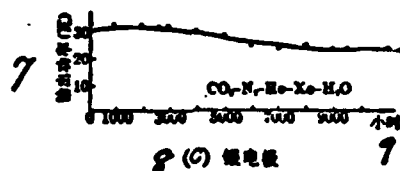
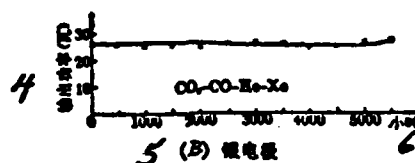
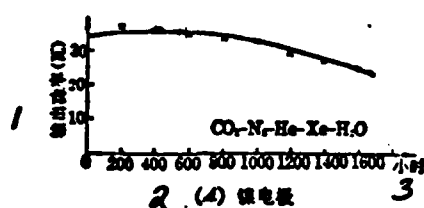
See table 2 for the long-life test results of various materials used for the sealed CO₂ laser. Fig. 2 shows that the output power changes with the time.

1 编 号	2 电极 材料	工作寿命 D(小时)	// 备 注
A	3 镍	1,644	寿命终止(1978.3.18→5.31) 12
B	4 银	1,514	因断水控制路失灵而炸裂 13 (1977.12.9→1978.8.8)
C	5 银	10,426	寿命终止 14 (1978.3.22→1979.6.23)
D	6 银	9,135	仍在运转(1978.8.31→现在) 15
E	7 银	9,237	仍在运转(1978.8.29→现在) 16
F	8 银	1,200	银电极与铜棒的连接处腐蚀 17 (1977.5.28→1977.9.21)
G	9 镍	43	因 CO 与 Ni 起化学反应的结果 18

Table 2

- Key: 1. Serial number
 2. Electrode material
 3. Nickel
 4. Silver
 5. Silver
 6. Silver
 7. Silver
 8. Silver
 9. Nickel
 10. Operating life (hours)
 11. Remarks
 12. Life terminated (1978.3.18 to 5.31)

13. Blew up because water breaking controller was not working (1977.12.9 to 1978.8.8)
14. Life terminated (1978.3.22 to 1978.6.23)
15. Still in operation (1978.8.31 to present)
16. Still in operation (1978.8.29 to present)
17. Connector wire of silver electrode and tungsten rod is nickel wire (1977.5.26 to 1977.9.21)
18. Result of chemical reaction caused by CO and Ni



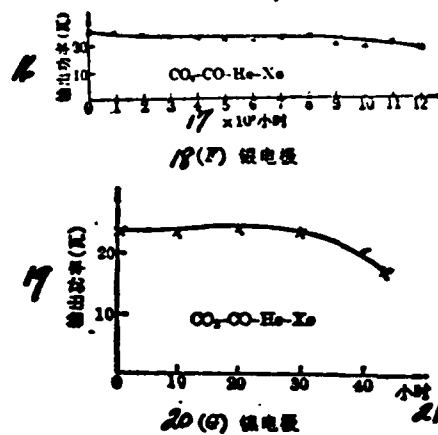


Fig. 2 Output Power Changes With Time

- Key:
1. Output power (watts)
 2. (A) Nickel electrode
 3. Hours
 4. Output power (watts)
 5. (B) Silver electrode
 6. Hours
 7. Output power (watts)
 8. (C) Silver electrode
 9. Hours
 10. Output power (watts)
 11. x 10² hours
 12. (D) Silver electrode
 13. Output power (watts)
 14. x 10³ hours
 15. (E) Silver electrode
 16. Output power (watts)
 17. x 10² hours
 18. (F) Silver electrode
 19. Output power (watts)
 20. (G) Nickel electrode
 21. Hours

III. Discussion

It can be seen from fig. 2 which shows output power changes with the time that the operating life varies with different electrode materials and different gas compositions. Based on test results, we think that there are three main factors which must be considered to obtain a sealed CO_2 laser with long-life.

1. Elimination of Slow Gas Leakage

Manufacturing technology for sealed CO_2 lasers must be strict. This includes the conditions that the manufacture of glass semi-finished products cannot have weak links and tungsten sintering. To guarantee all technological aspects when gluing the wafer we can eliminate slow gas leakage.

2. Selection and Oxidation of Electrode Material

As regards the cold cathode of the CO_2 laser, we select a material with very low sputtering rate for the cathode. This type of material does not separate the gas because of the sputtering and avoids undergoing a chemical reaction and consuming any gas compounds. This is very important.

Nickel is a widely used electrode material in sealed CO_2 lasers. Although its sputtering is less than other metals yet when it reacts with the CO_2 and is decomposed into CO the formed carbonyl nickel ($\text{Ni}(\text{CO})_5$) can spoil the electrode. Moreover, because of the decomposed O which continually consumes CO_2 molecules the CO cannot again form CO_2 . Therefore, when a nickel electrode is used this makes it more difficult for the

sealed CO_2 laser to obtain long-life.

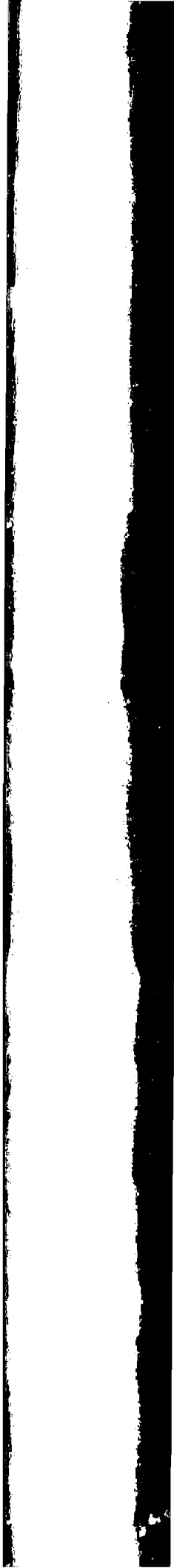
When we change to use pure silver as the electrode material, because the silver and CO do not cause a reaction and the compound of O and silver is very reactive, when in $200-300^\circ\text{C}$, the oxide of silver can be reduced to form pure silver. Therefore, the use of a silver electrode can cause the sealed CO_2 laser to reach long-life. Because the sputtering of silver is relatively strong it can be suitable for lengthening the distance from the window to the electrode. In this way, we can decrease or eliminate the sputtering substances on the window plate.

Furthermore, the oxidation of the electrode is very important. If the nickel electrode does not undergo oxidation, its operating life will only be 500-600 hrs but if it undergoes oxidation its operating life will be 1644 hrs.

oxygen gas so that a uniform oxidation layer will first form on the surface of the electrode. The aim is that during the discharge process as little oxygen as possible will be consumed and at the same time this can cause the decomposed product to again synthesize CO_2 . Besides this, after oxidizing the electrode there is little escaped energy of the electrons and there is also a decrease in sputtering. Because there is less absorbed gas caused by sputtering, operation life increases.

3. Decreasing the Decomposition of CO_2 Molecules

During the discharge process, a portion of the CO_2 molecules decompose:



suddenly go out. Therefore, when CO is used to replace N_2 and the $He-H_2O$.

After replacing N_2 with CO, its the current voltage of adding a electron temperature is also use of the decomposition of the to extending long-life. After CO operating life exceeds 5,514 hours already reached 9,185 hours and The output power which changes and (D) of fig. 2.

long-life and not cause output power over electrode. There is CO in the that is, $CO_2-N_2-CO-He-Xe-H_2O$. The 1. Operating life has reached operating normally.

Using pure silver electrodes with a $N_2-He-Xe-H_2O$ we can also obtain to 10,476 hours. The output power is shown in (B) of fig. 2. The CO_2 laser with added N_2 is 30 watts 6 hours the output power is still

21 watts. By using CO to replace N_2 the operating life close to 10,000 hours. This explains the oxide of the nitrogen is still using silver electrodes.

When manufacturing CO_2 H_2O is added. The effect of catalytic effect in the discharge noticeable effects on output is advantageous to the reverse the CO_2 laser's energy level quickens the composite of the the quantity of CO_2 decomposition long-life of the sealed CO_2

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